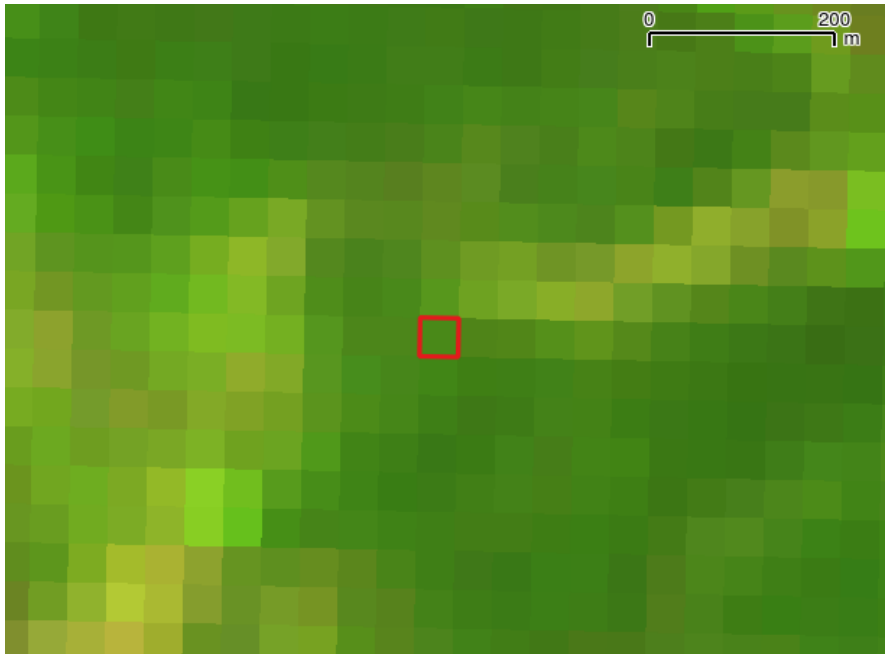
Making better use of what we already know in the analysis of Landsat times series

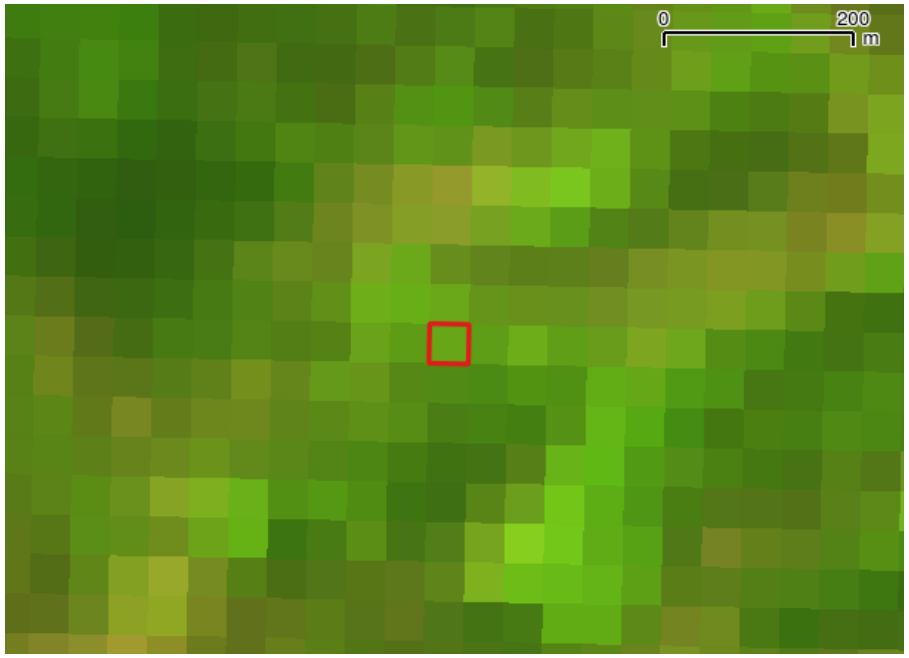
- Curtis Woodcock (talking head)
  - Val Pasquarella
  - Chris Holden
  - Paulo Arevola
  - Shixiong Wang
  - Xiaojing Tang
  - Eric Bullock

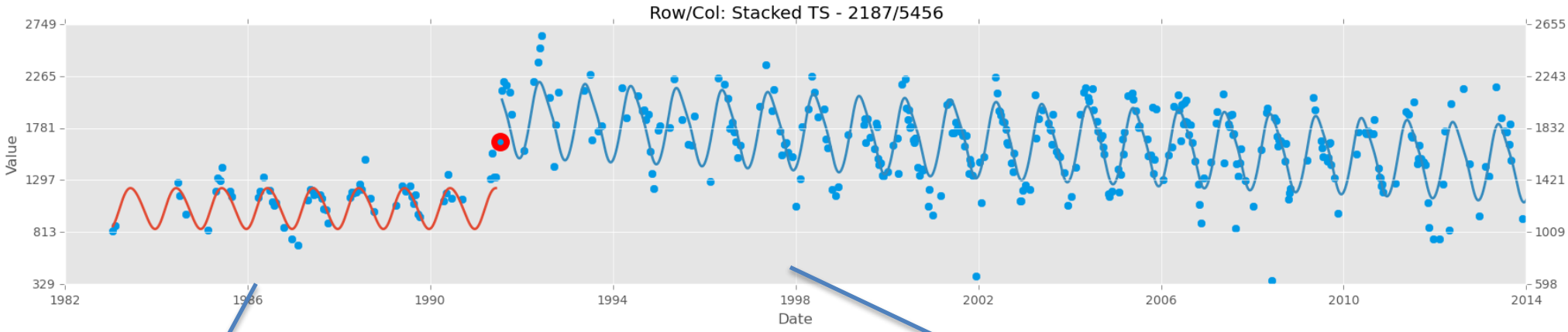
Two Points

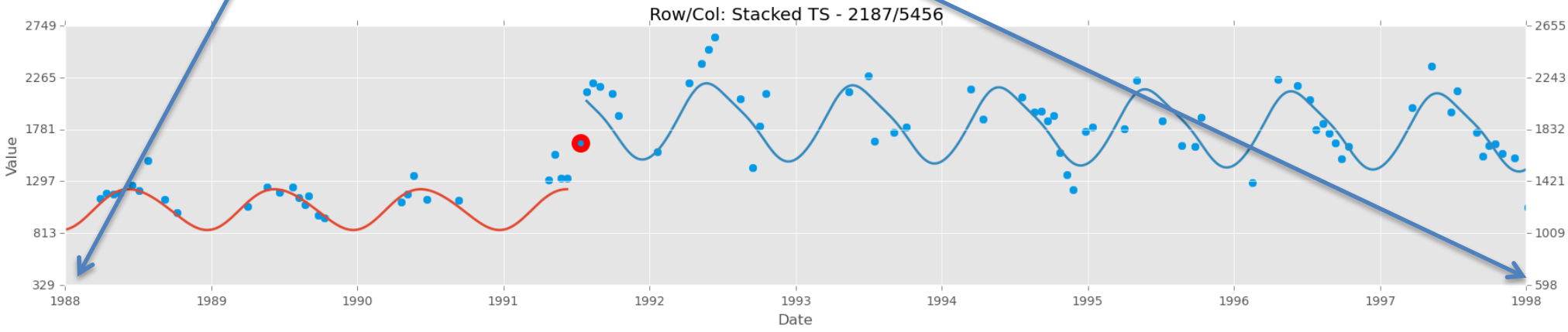
- In the process of moving from general time series analysis to targeted use of time series
- There are many time-series based features that many will want to use and should become a new set of Landsat products



Older thin (notice the Regrowth)



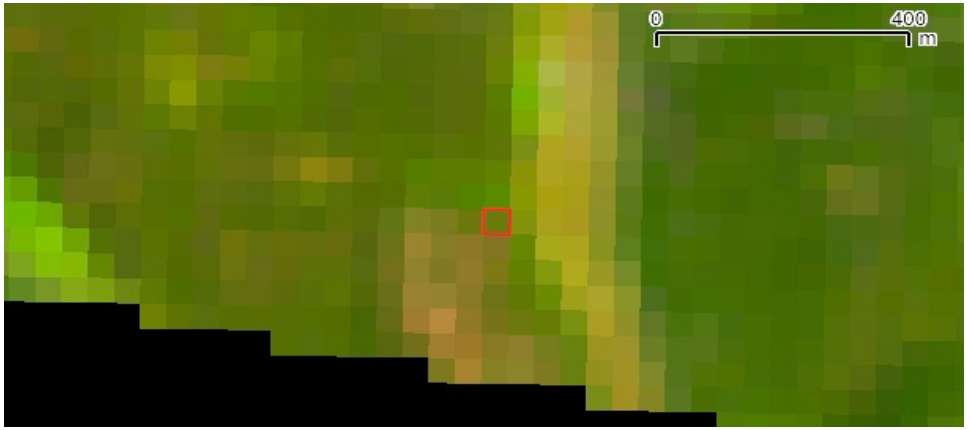


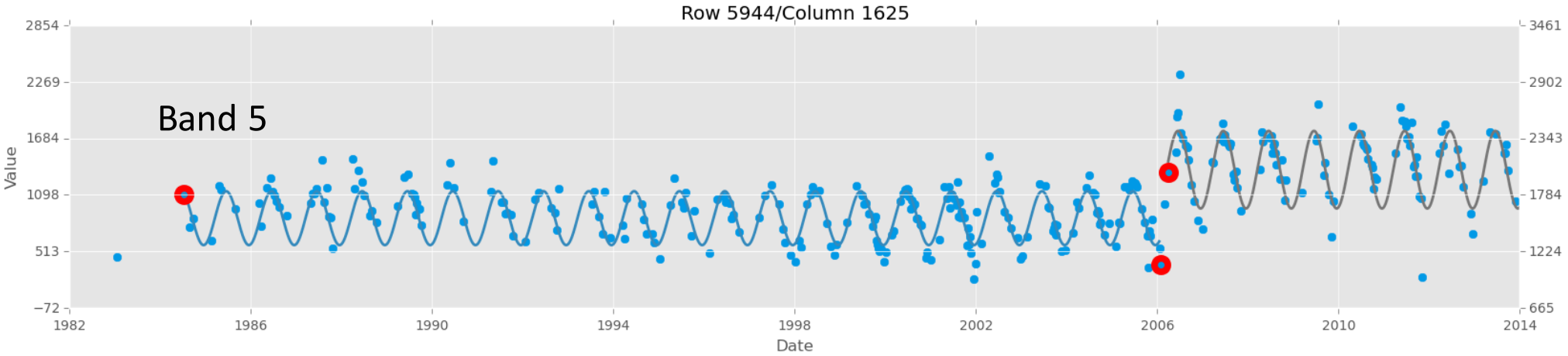


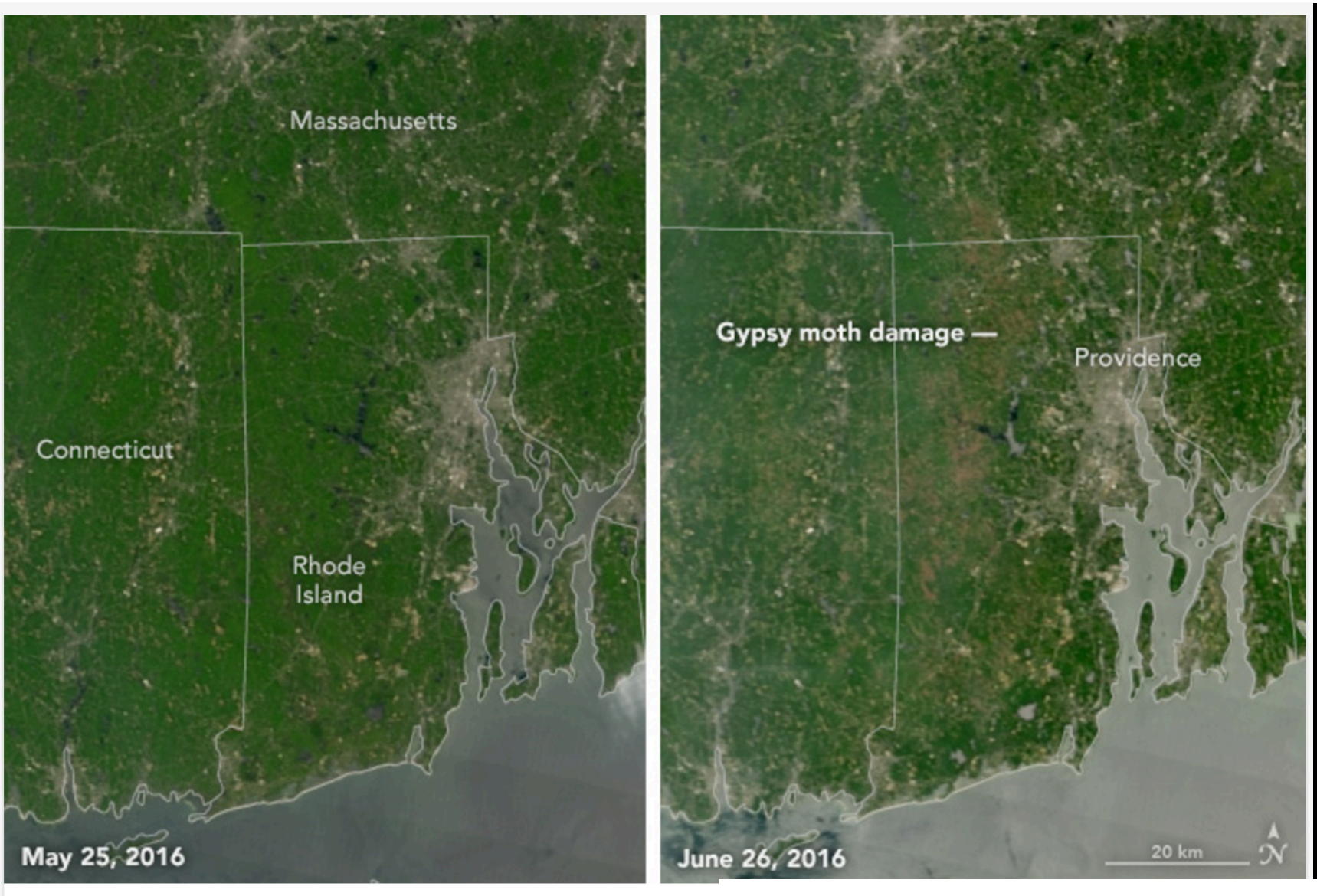
Beetle Damage at Mark's

2005

2006



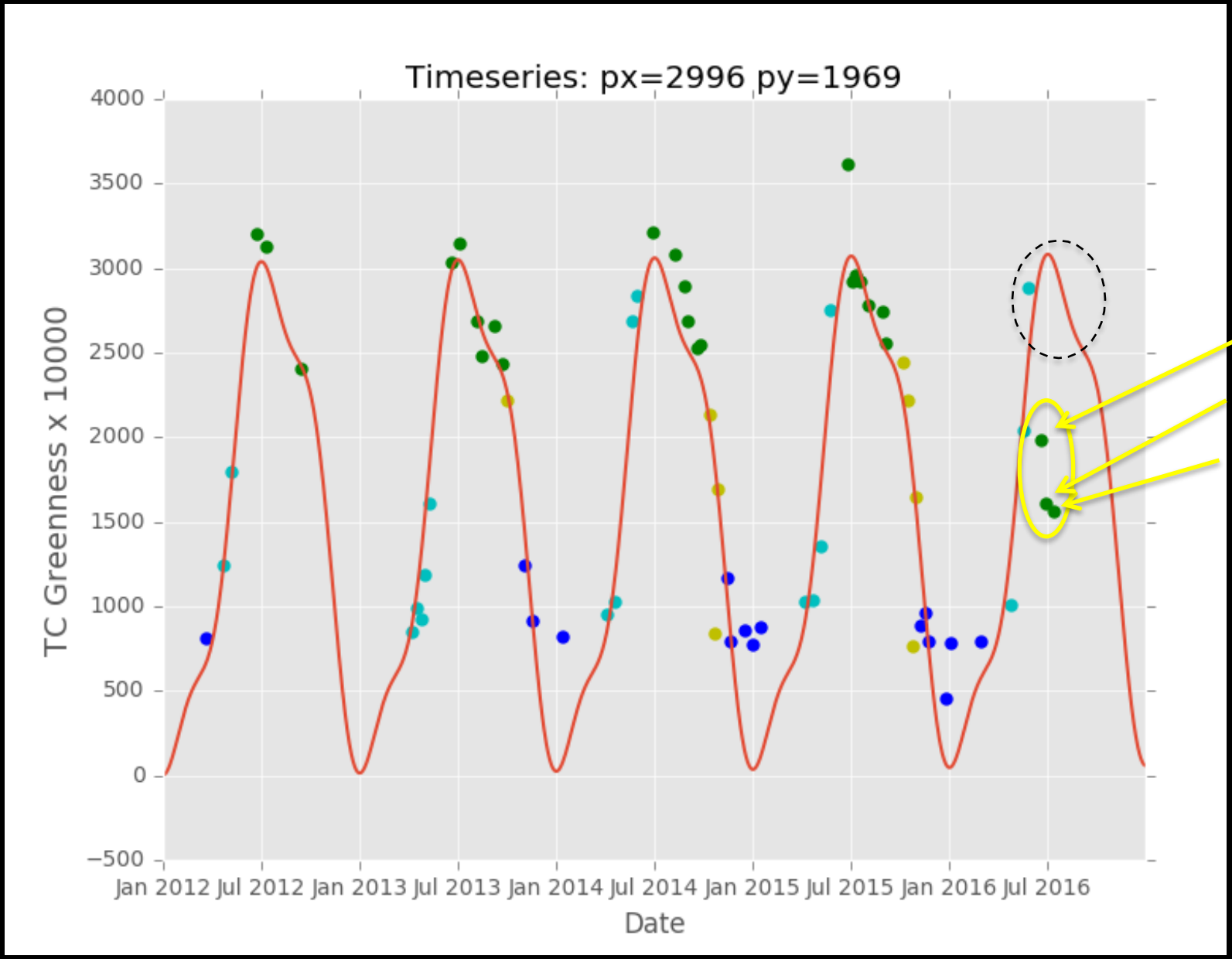


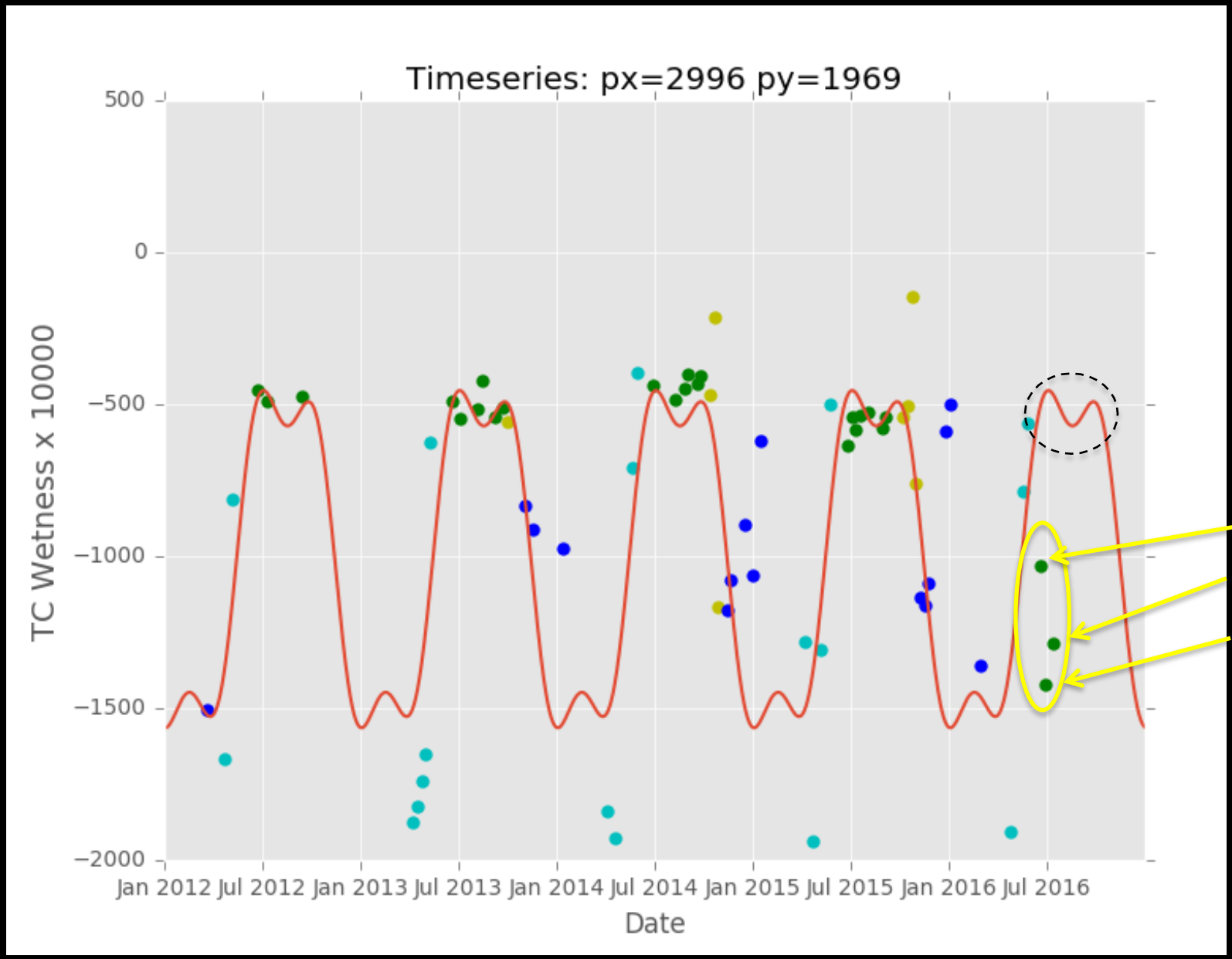


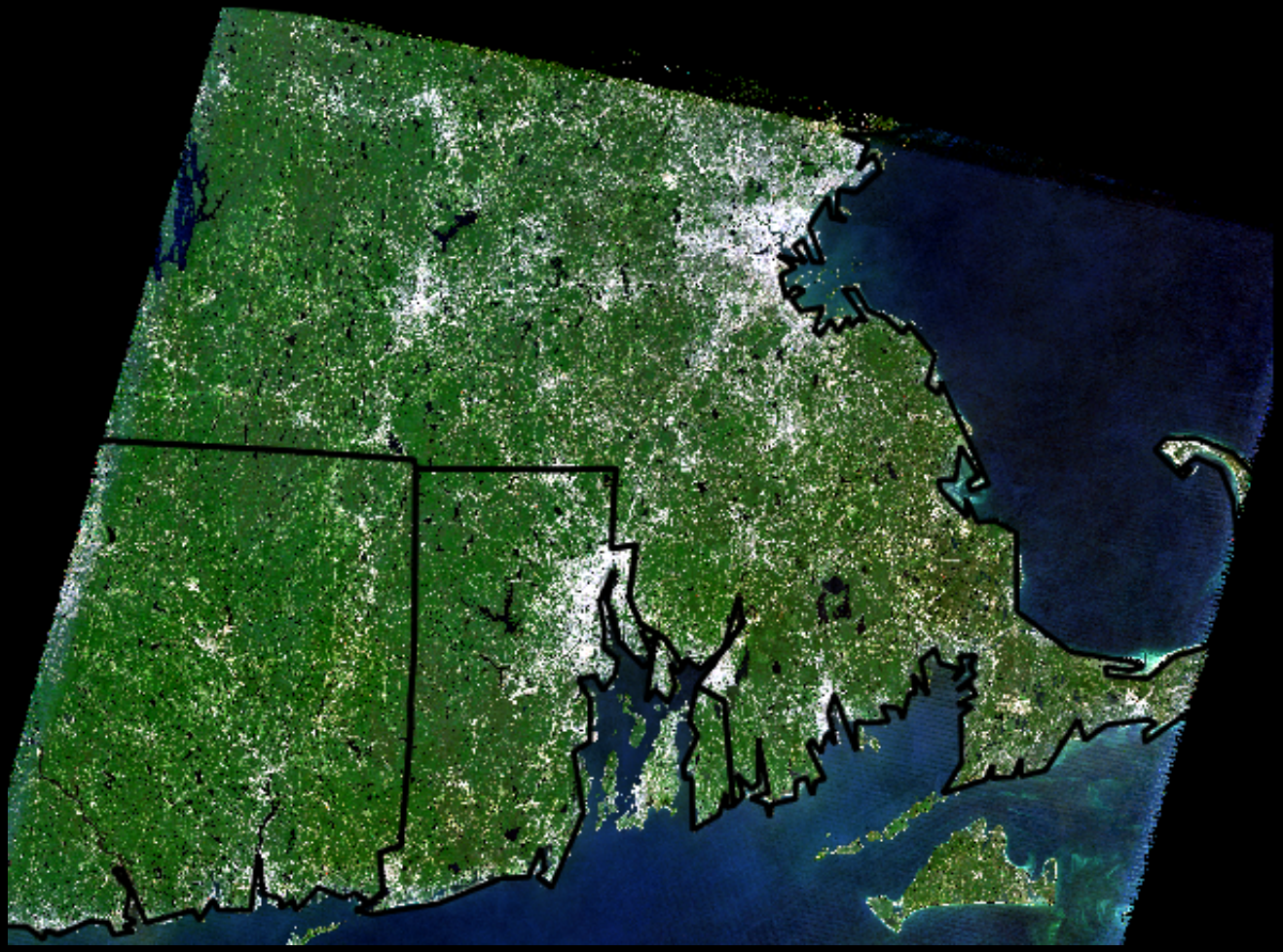
http://earthobservatory.nasa.gov/IOTD/view.php?id=88370

NASA EARTH OBSERVATORY

The natural-color images above were acquired by Terra's Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on May 25, 2016 (left), and June 26, 2016 (right). Healthy forests appear green, while defoliated areas have a gray-brown tint.


Timeseries: px=2996 py=1969
TC Greenness x 10000
4000
3500
3000
2500
2000
1500
1000
500
0
−500
Jan 2012
Jul 2012
Jan 2013
Jul 2013
Jan 2014
Jul 2014
Jan 2015
Jul 2015
Jan 2016
Jul 2016
Date
06/19
06/27
07/13
Summer
Spring
Winter
Autumn

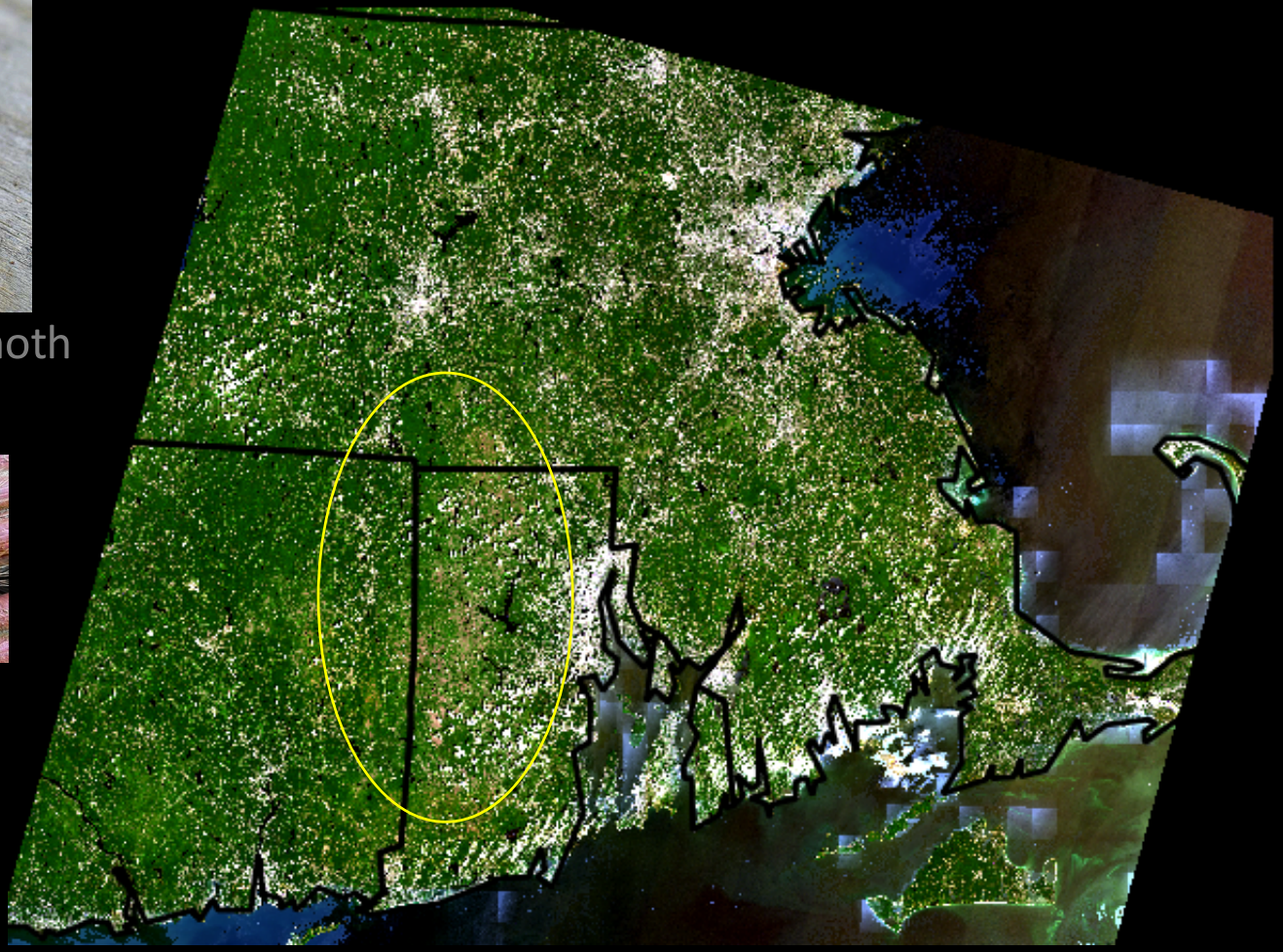

Timeseries: px=2996 py=1969
500
0
−500
−1000
−1500
−2000
TC Wetness x 10000
Jan 2012
Jul 2012
Jan 2013
Jul 2013
Jan 2014
Jul 2014
Jan 2015
Jul 2015
Jan 2016
Jul 2016
Date
06/19
06/27
07/13
Summer
Spring
Winter
Autumn



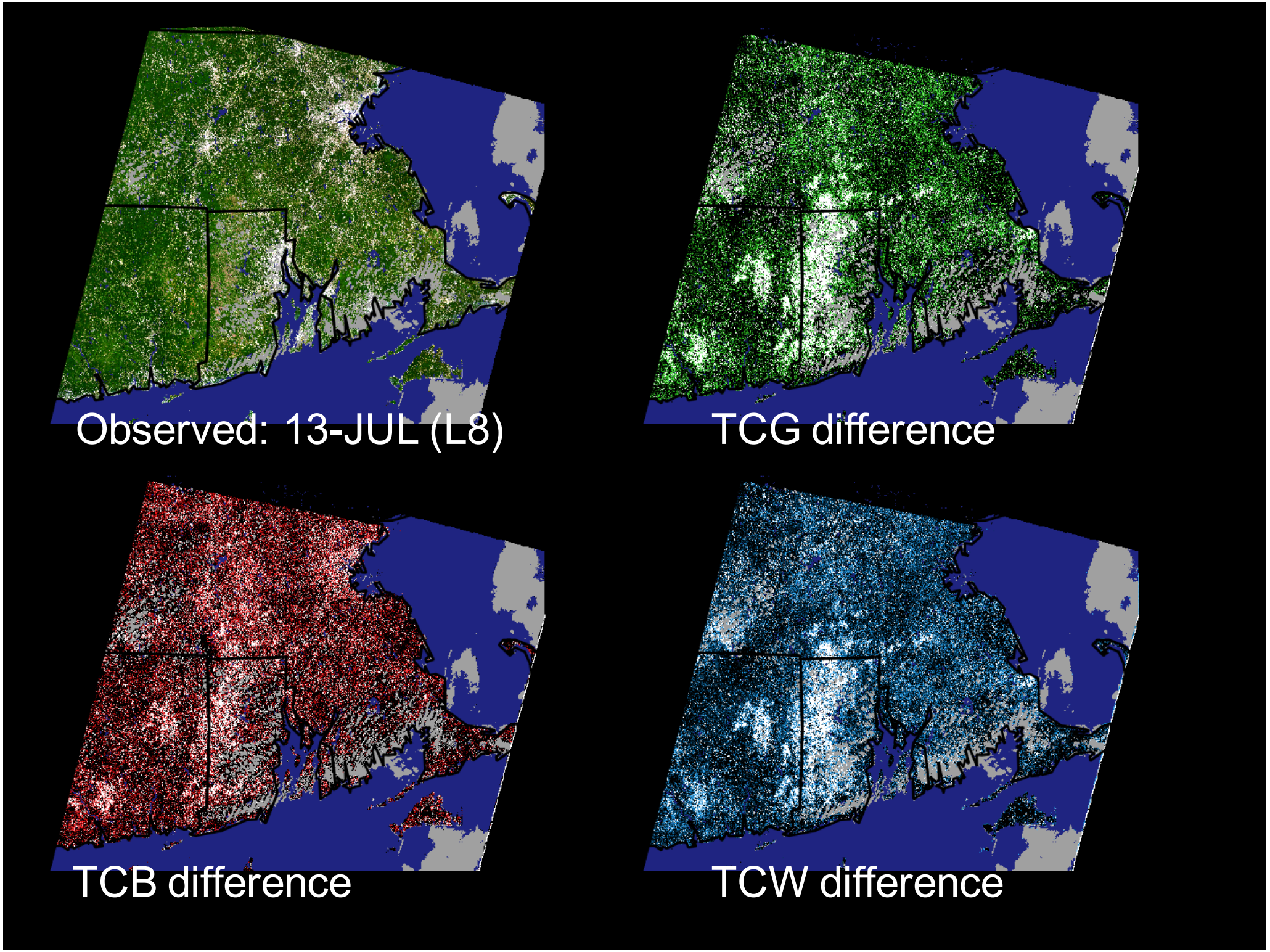
Predicted: 2016-195 (JUL-13)

CCDC fit, 01/01/2005 – 06/27/2016
Annual and 4-month harmonics
Conservative parameterization

European gypsy moth
(*Lymantria disbar*)

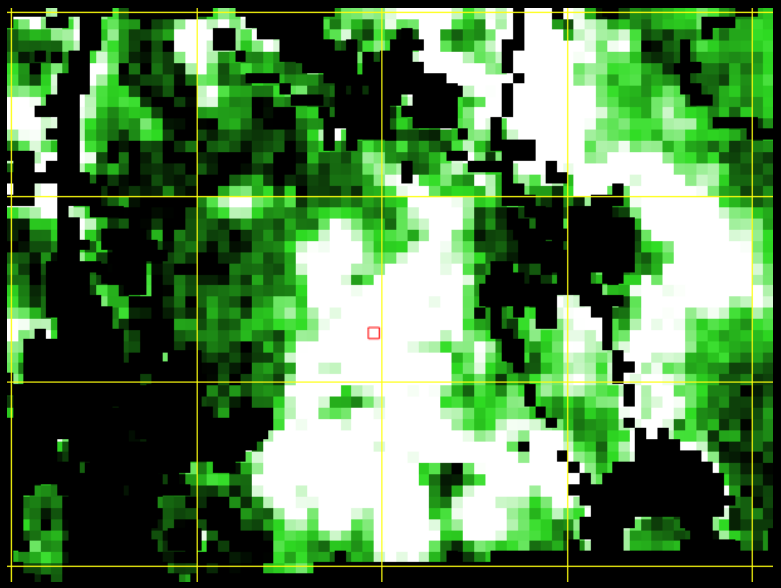


Observed (L8): 2016-195 (JUL-13)

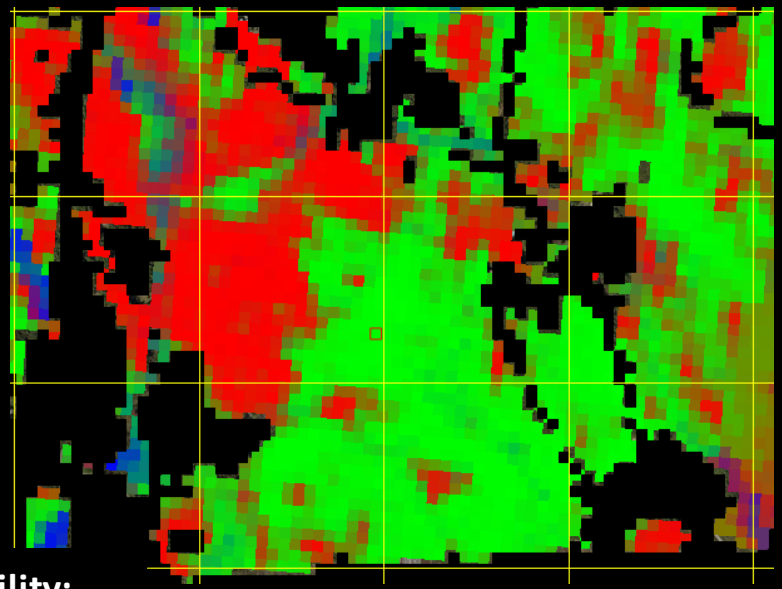

Observed: 13-JUL (L8)
TCG difference
TCB difference
TCW difference

High res w/ 500m grid

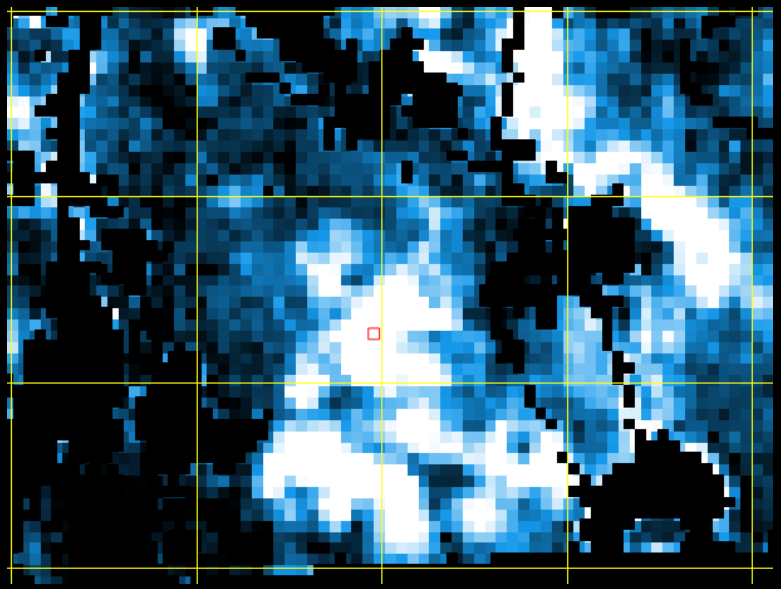
TCG difference



General forest type



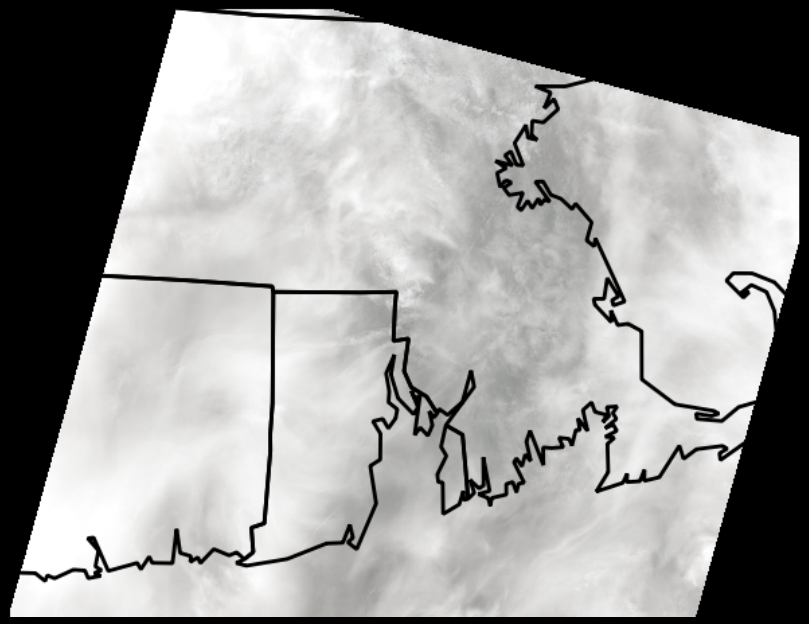
TCW difference



RF Probability:

- Conifer
- Hardwood
- Swamp

Example



06/11/2016 (L8)

06/19/2016 (L7)

06/27/2016 (L8)

07/13/2016 (L8)

Lessons Learned: Gypsy Moths

With prior time series it is easy to find damage very shortly after having new image data available

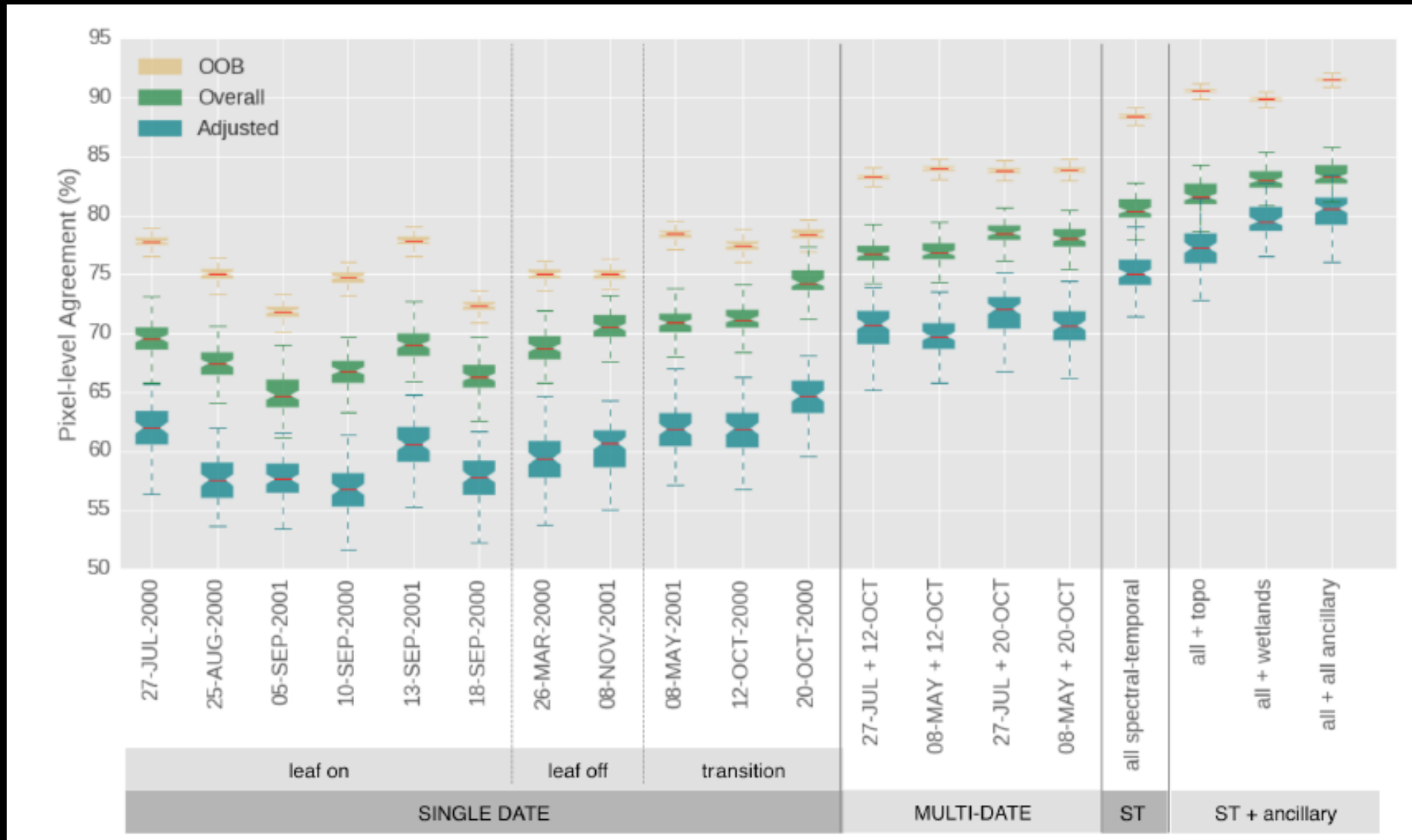
It will be interesting to watch recovery in future years

With more observations it is possible to discern more subtle changes in the landscape

More frequent observations will improve the value of Landsat for land management

mapping of forest composition using spectral-temporal features

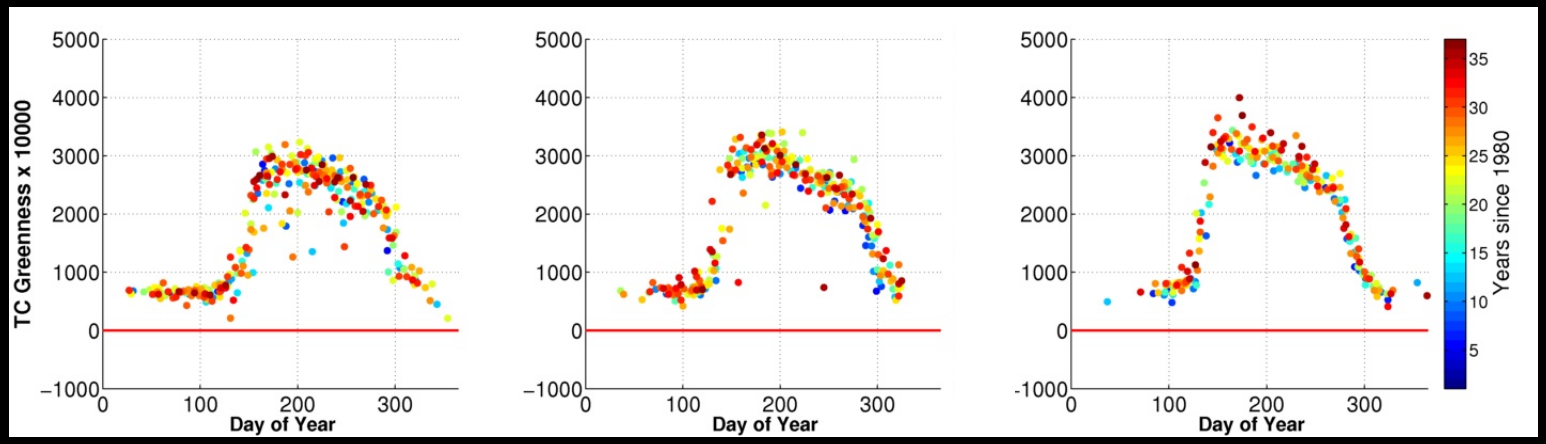
(Valerie Pasquarella)


OOB
Overall
Adjusted
Pixel-level Agreement (%)
95
90
85
80
75
70
65
60
55
50
27-JUL-2000
25-AUG-2000
05-SEP-2001
10-SEP-2000
13-SEP-2001
18-SEP-2000
26-MAR-2000
08-NOV-2001
08-MAY-2001
12-OCT-2000
20-OCT-2000
27-JUL + 12-OCT
08-MAY + 12-OCT
27-JUL + 20-OCT
08-MAY + 20-OCT
all spectral-temporal
all + topo
all + wetlands
all + all ancillary
leaf on
leaf off
transition
SINGLE DATE
MULTI-DATE
ST
ST + ancillary

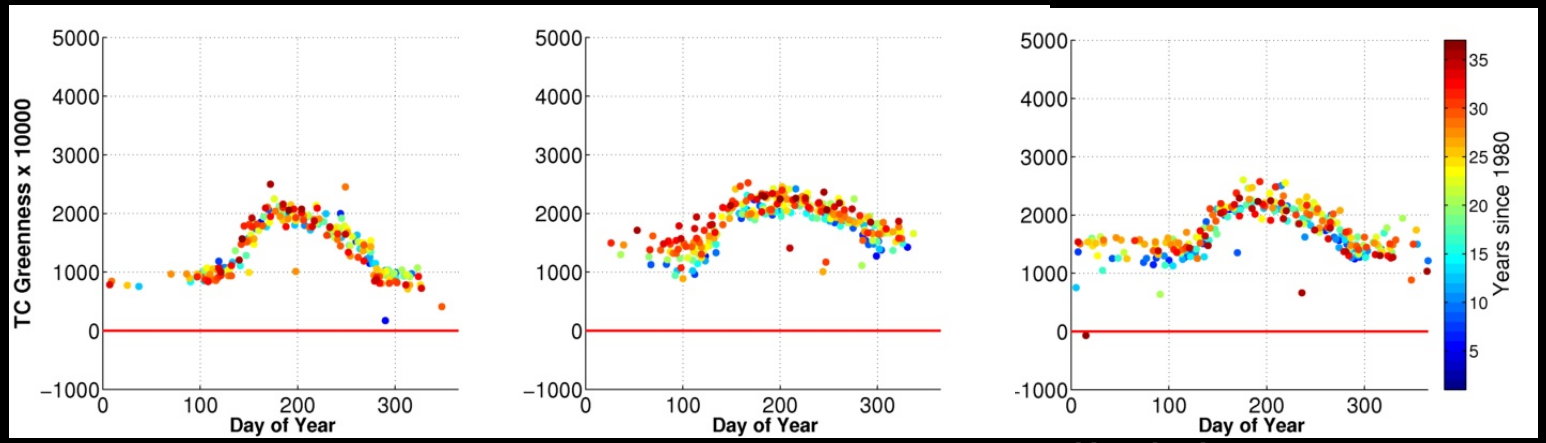
Spatial-Temporal Features (Inputs to Classification):

- Spectral Bands and indices (B,G,W):
  - intercepts (annual means)
  - Annual Amplitudes
  - RMSE
- Phenology:
  - Day of Year Onset, Offset, Peak EVI
  - Peak EVI

Seasonal profiles - Greenness

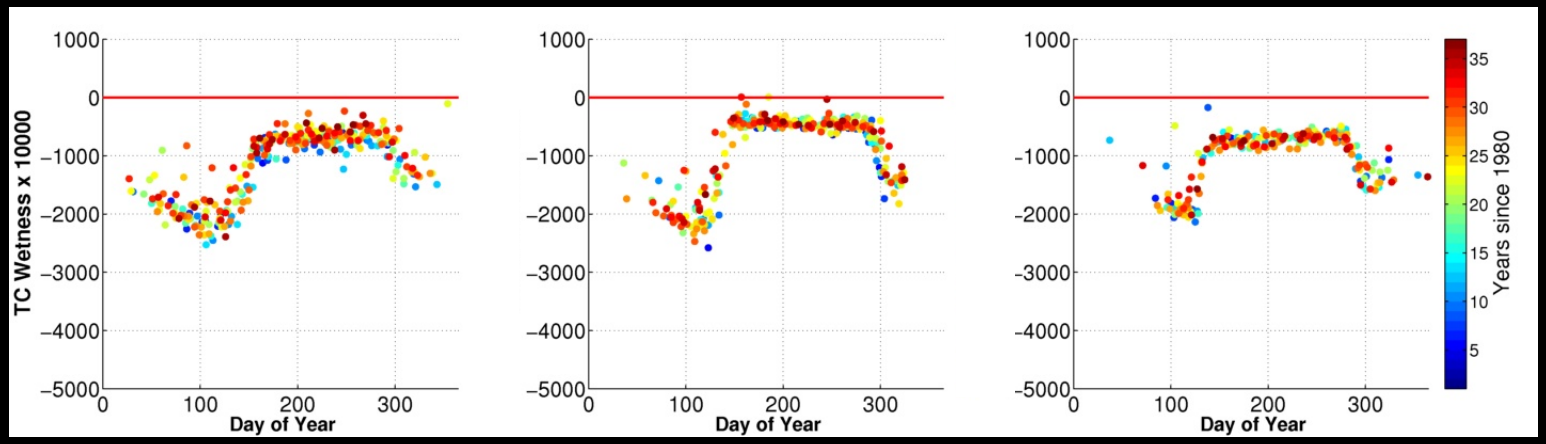


Coastal Oak | Central Hardwoods | Northern Hardwoods

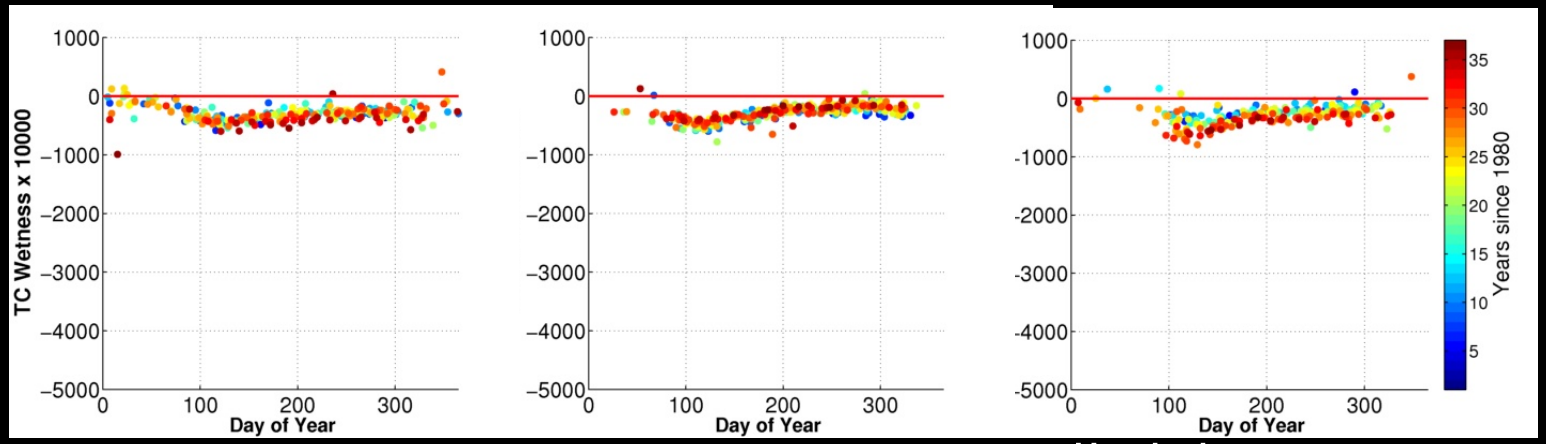


Spruce-Fir | Planted Pine | Hemlock

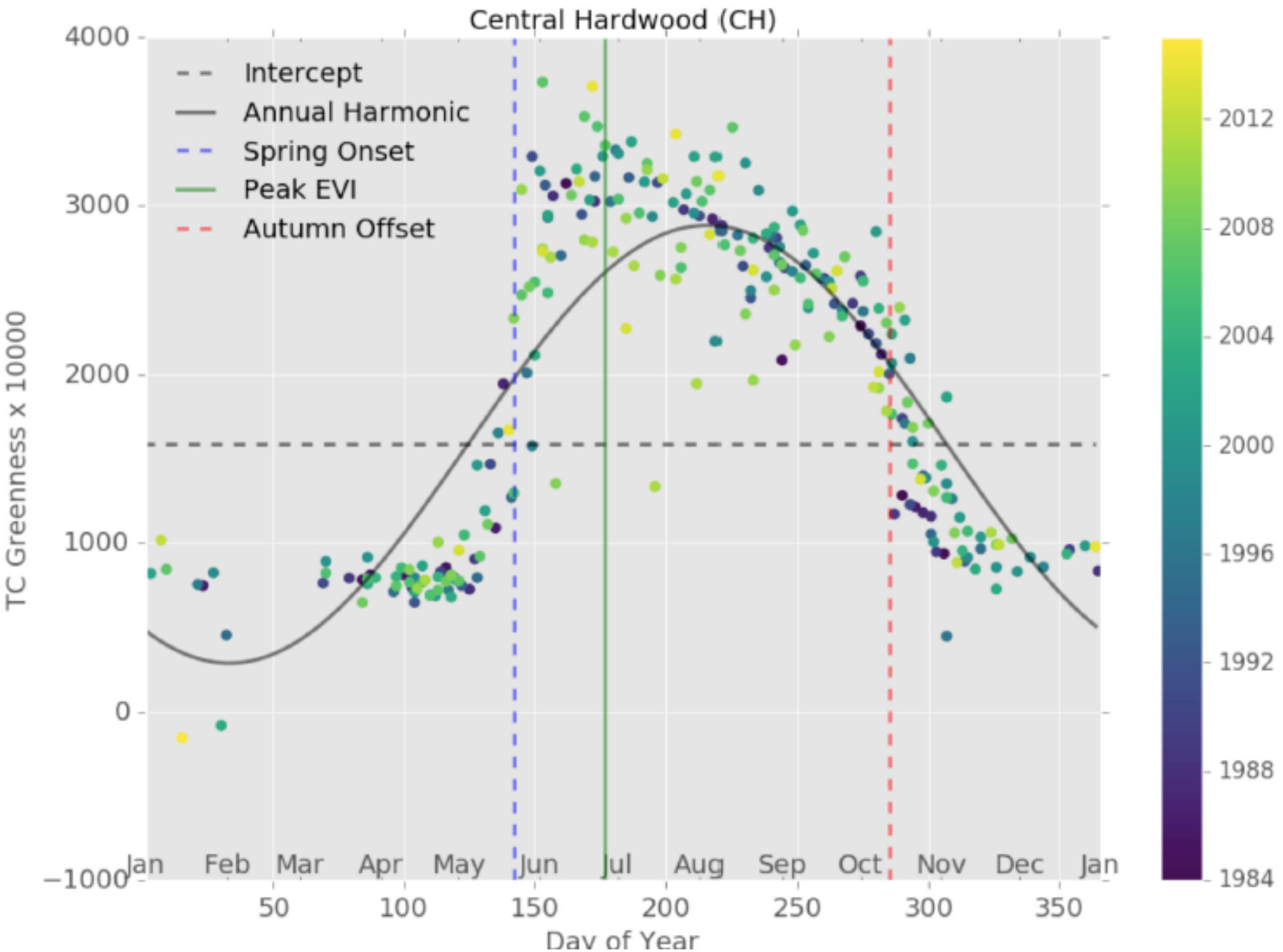
Seasonal profiles - Wetness



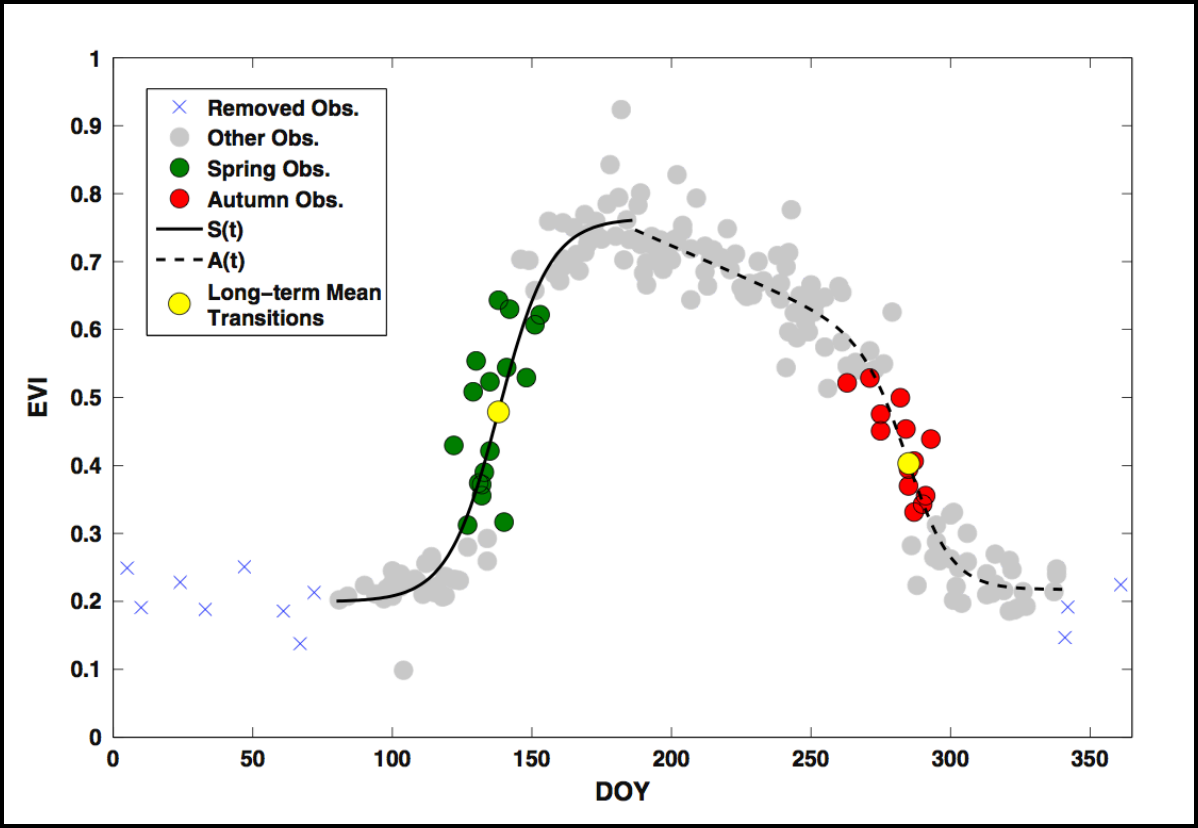
Coastal Oak | Central Hardwoods | Northern Hardwoods



Spruce-Fir | Planted Pine | Hemlock

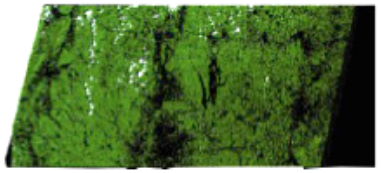

Central Hardwood (CH)
Intercept
Annual Harmonic
Spring Onset
Peak EVI
Autumn Offset
TC Greenness x 10000
4000
3000
2000
1000
0
−1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
50
100
150
200
250
300
350
Day of Year
2012
2008
2004
2000
1996
1992
1988
1984

Phenology



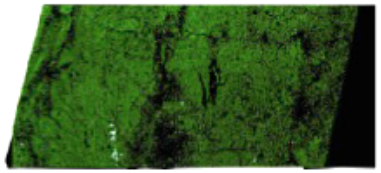
Melaas, E. K., Friedl, M. A., & Zhu, Z. (2013). Remote Sensing of Environment. *Remote Sensing of Environment*, *132*(C), 176–185. http://doi.org/10.1016/j.rse.2013.01.011

LEAF-ON

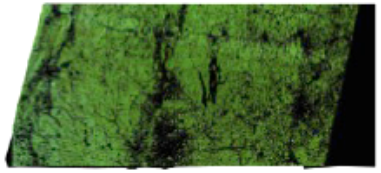


2001-JUL-27 (LT5)

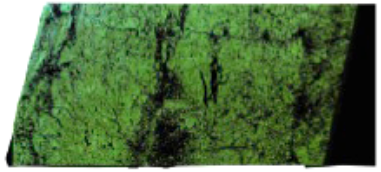
2000-AUG-25 (LT5)



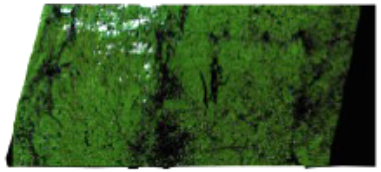
2001-SEP-05 (LE7)



2000-SEP-10 (LT5)



2001-SEP-13 (LT5)



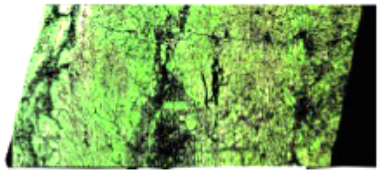
2000-SEP-18 (LE7)

LEAF-OFF

2001-NOV-08 (LE7)

2000-MAR-26 (LE7)

TRANSITION



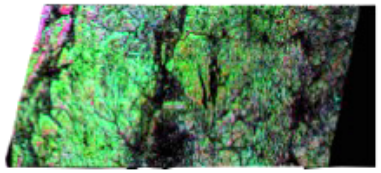
2001-MAY-08 (LT5)

2000-OCT-12 (LT5)

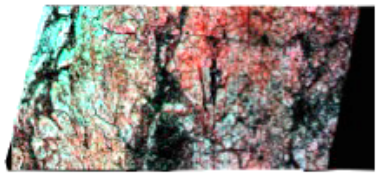
2001-OCT-20 (LE7)

Red (Band 3)
Green (Band 2)
Blue (Band 1)

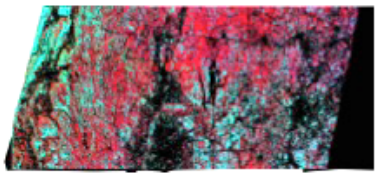
CCDC – TS Harmonics



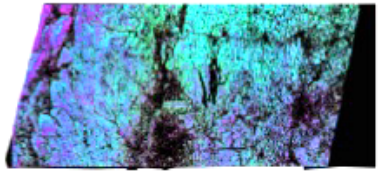
TC Brightness



TC Greenness



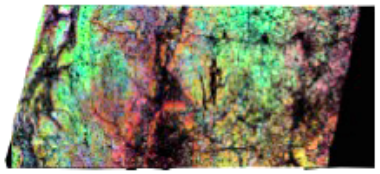
TC Wetness



Brightness Temp

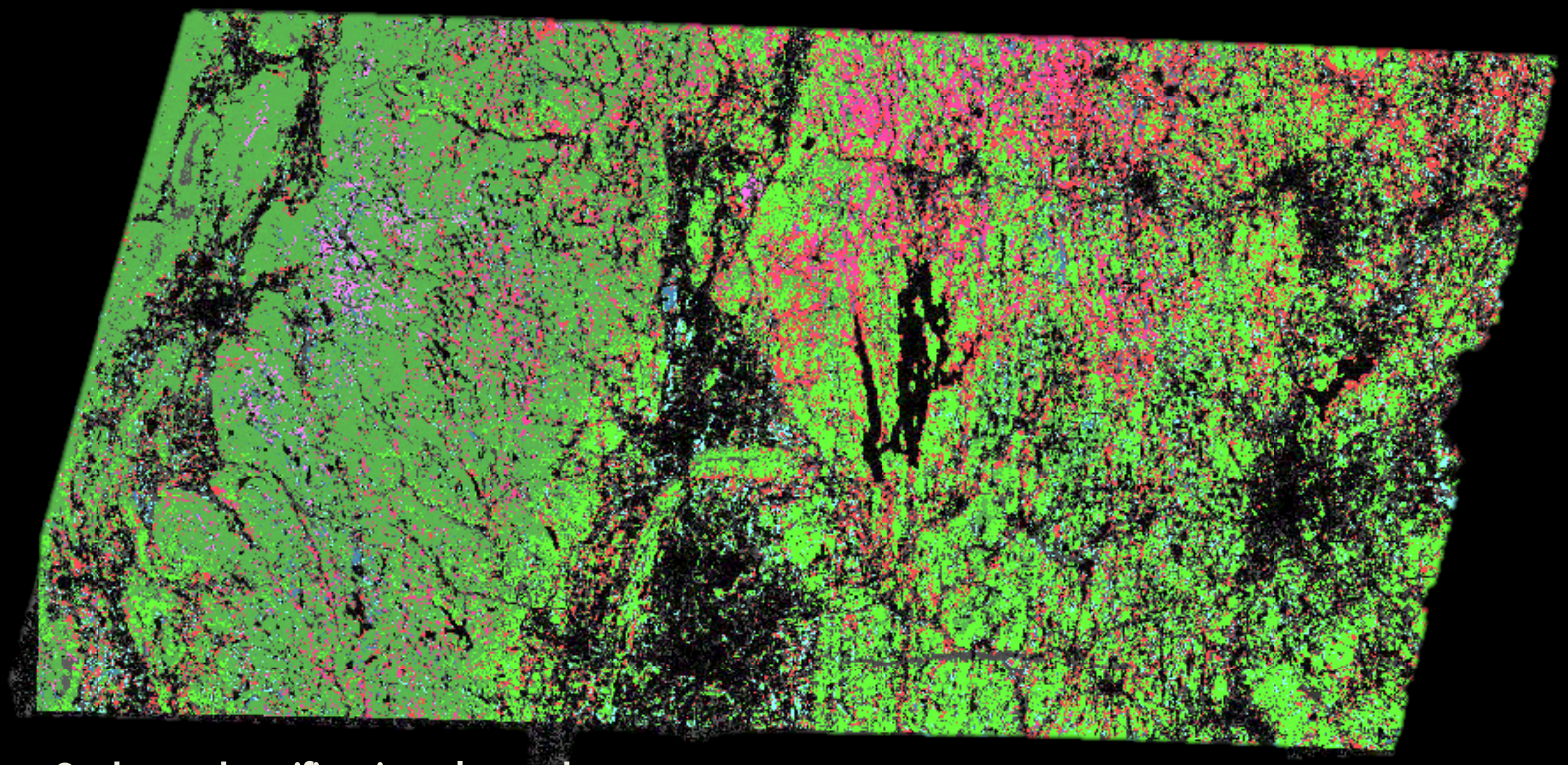
Intercept
Annual amplitude
RMSE

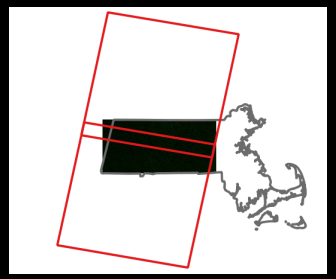
TS Phenology



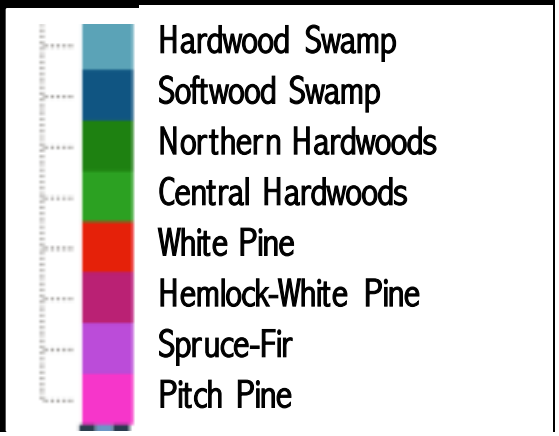
Phenology

Autumn Onset
Spring Onset
DOY of Peak EVI





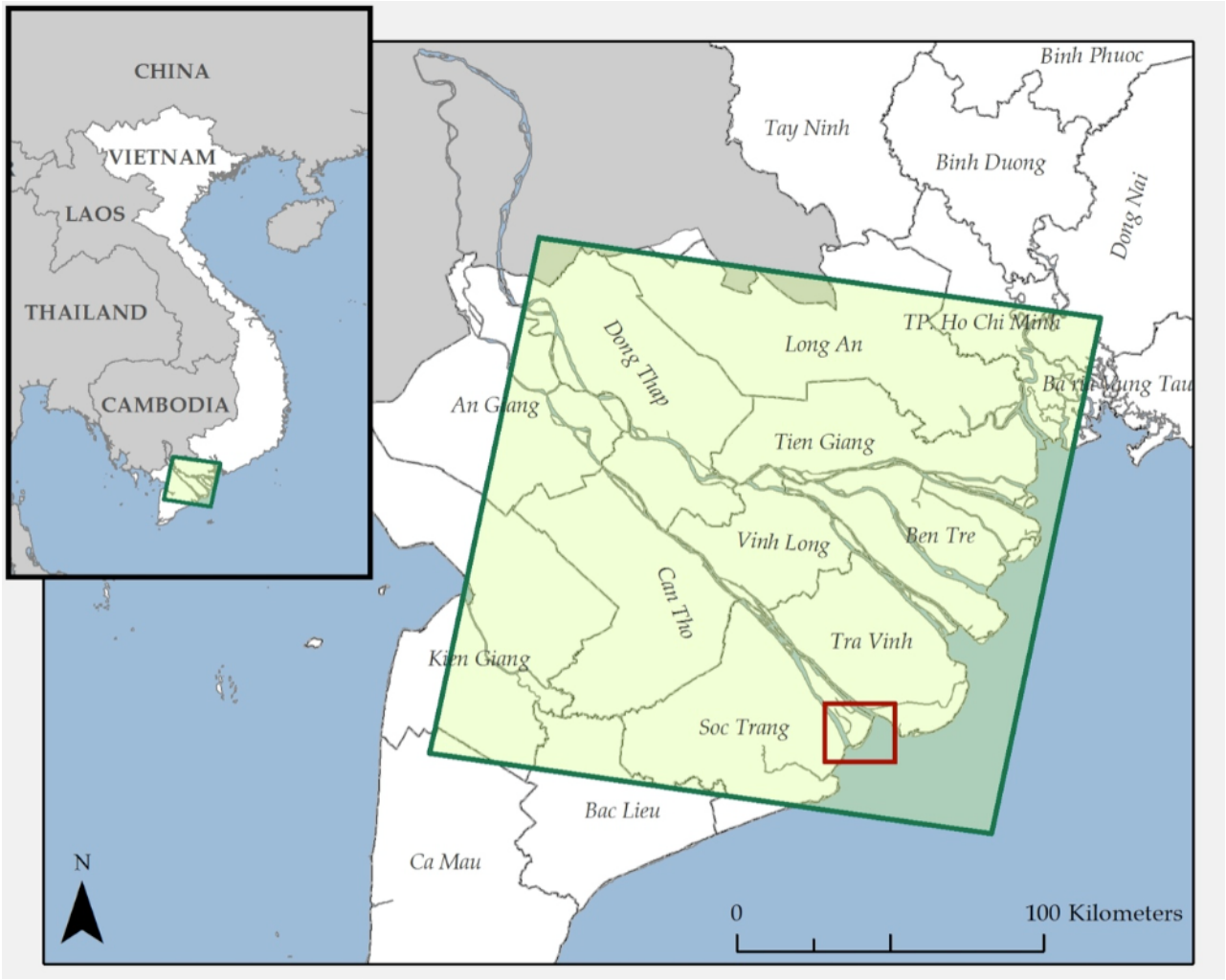
8-class classification based on
DFW Land Cover Data Layer, Forest Matrix Types



Lessons Learned: Forest Composition Mapping

- Use of all available data allows for a much richer set of spectral-temporal features for use in image classification
- Tests on mapping of forest composition indicate the ability to provide a new level of categorical detail
- The spectral-temporal features based on time series analysis can be generated in a consistent way across space and time improving the opportunity for large area mapping

Mekong Delta – Monitoring growth of mangroves and species transitions (Eric Bullock, Sergio Fagherazzi, Valerie Pasquarella)



BOSTON UNIVERSITY

1989-096

2015-152

BOSTON UNIVERSITY

Mangrove Expansion*

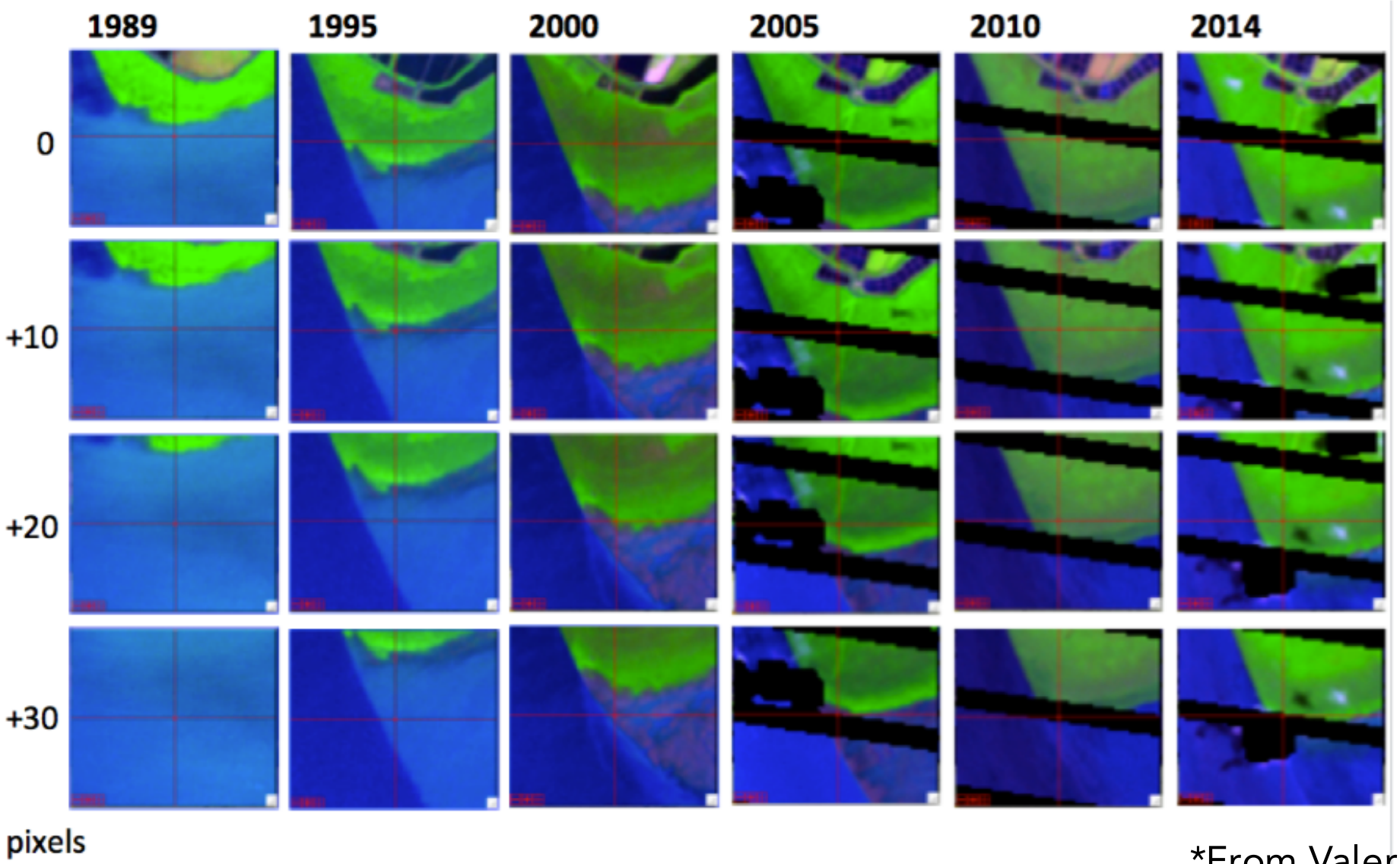
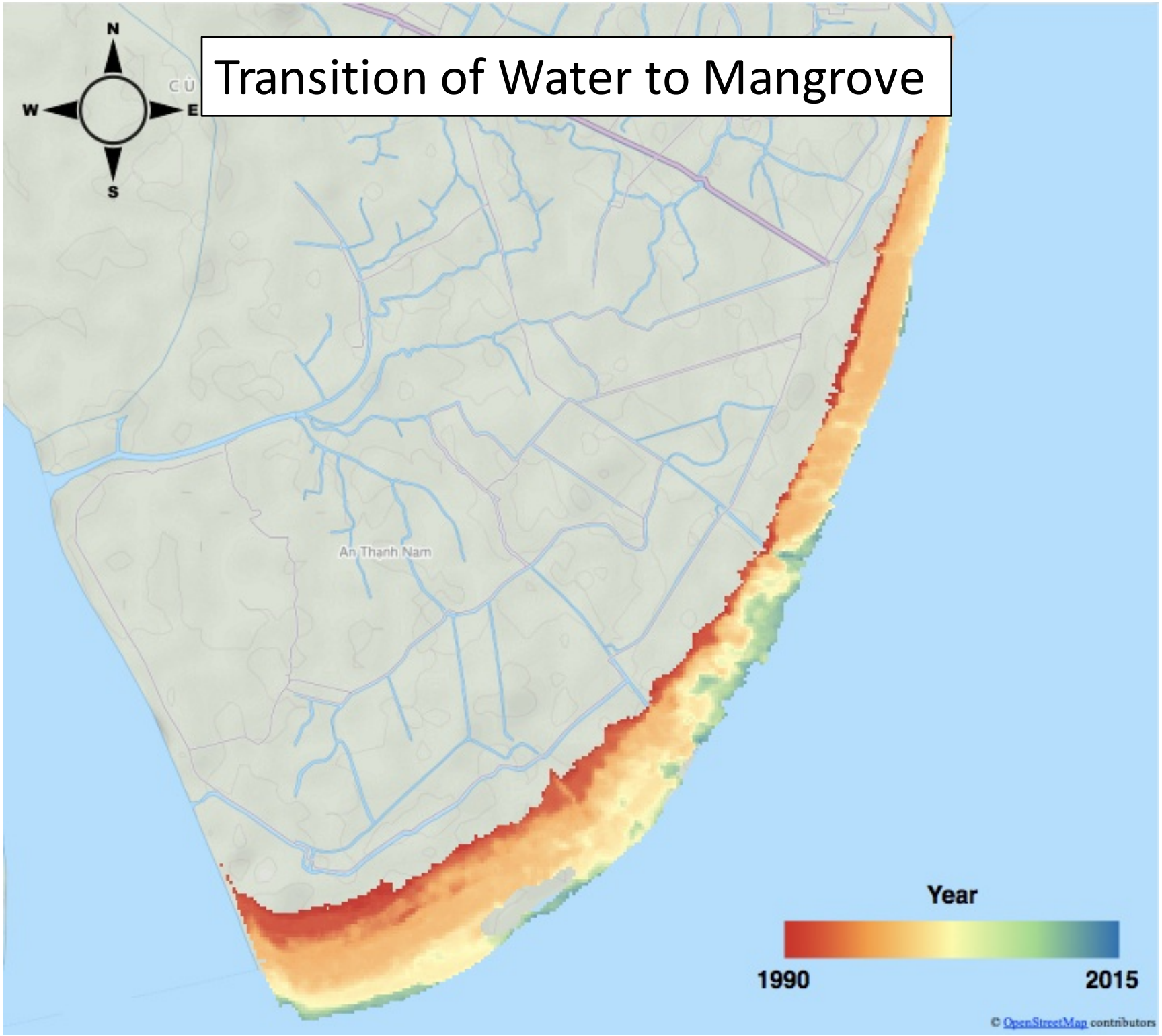


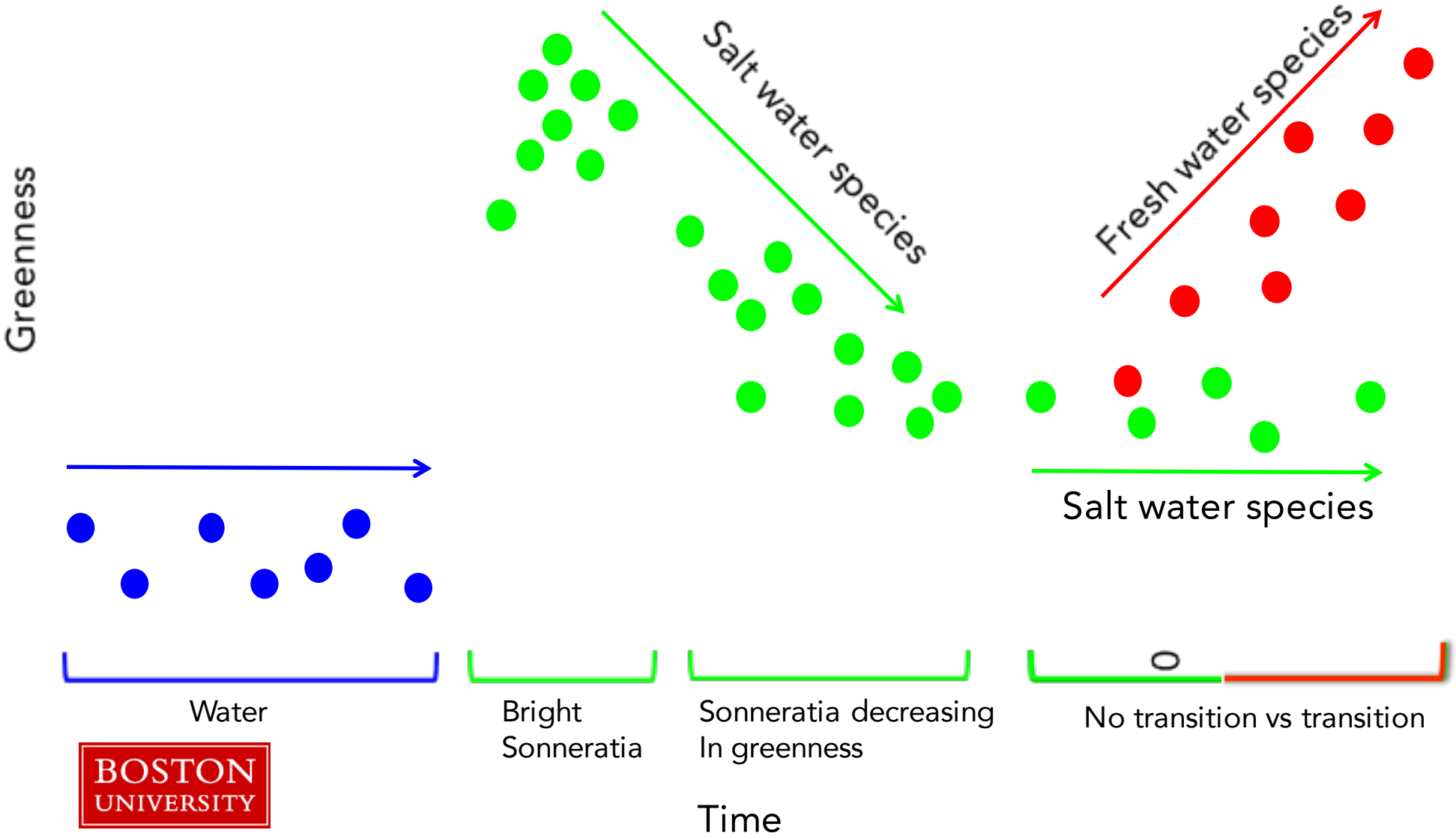
Figure 5: Spatio-temporal change (land building)

*From Valerie Pasquarella 201


Transition of Water to Mangrove
N
W
E
S
An Thanh Nam
Year
1990
2015
© OpenStreetMap contributors


Fresh Water sp.
Mixed
Salt Water sp. (Sonneratia)
= Sample Transect 03/2015

Sample ‘Greenness’ Time Series



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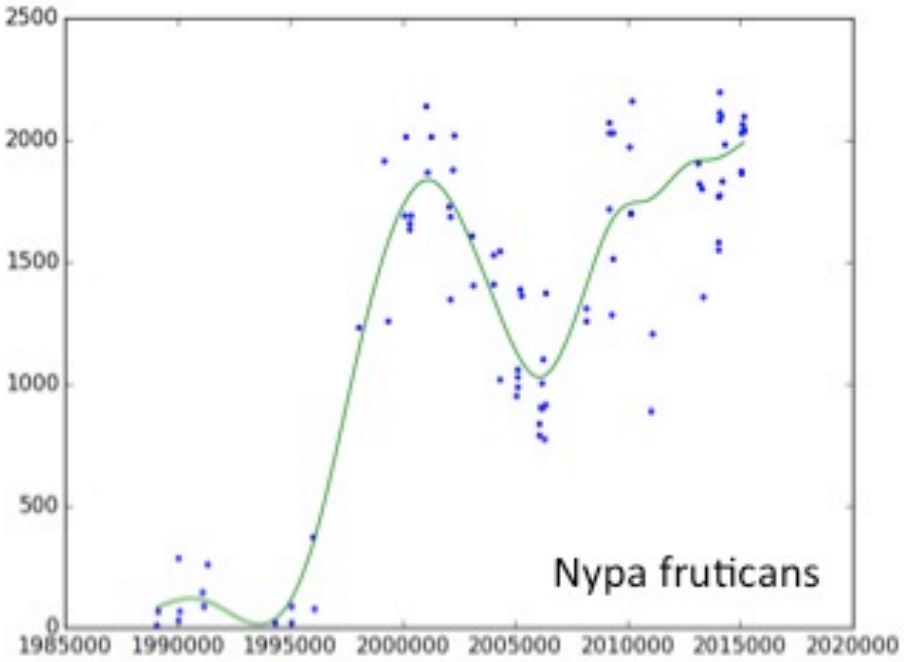
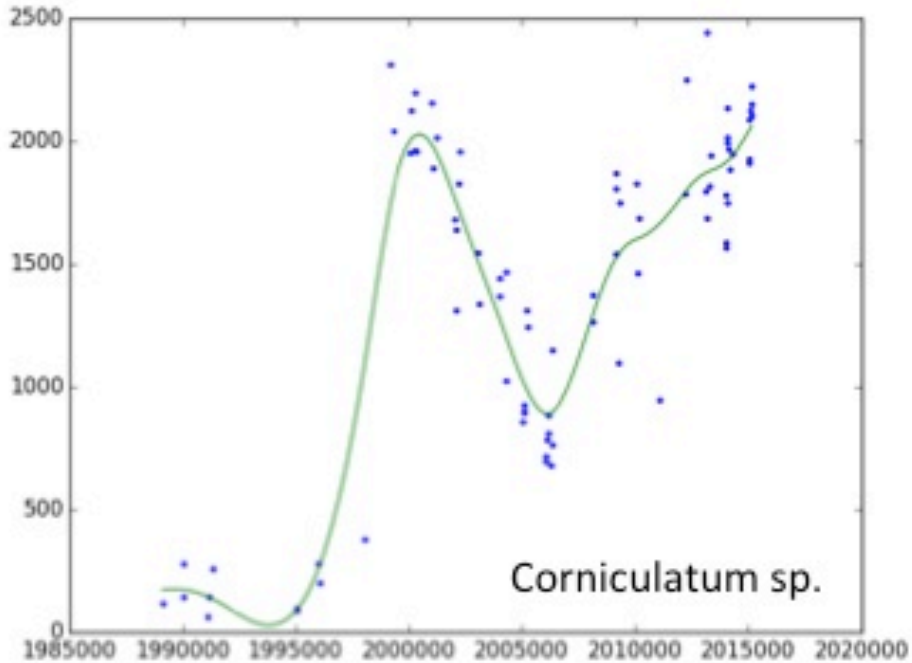
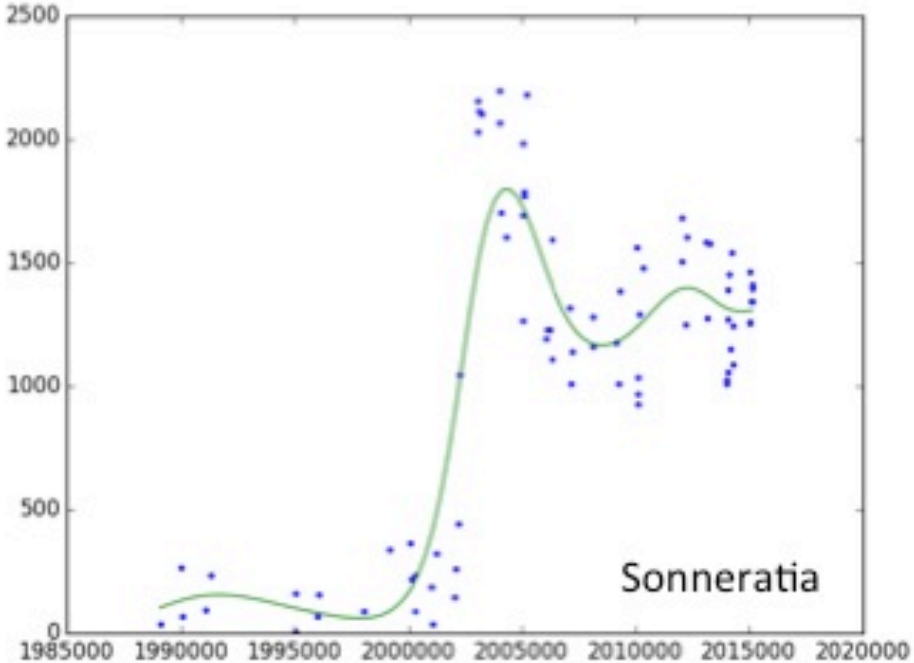
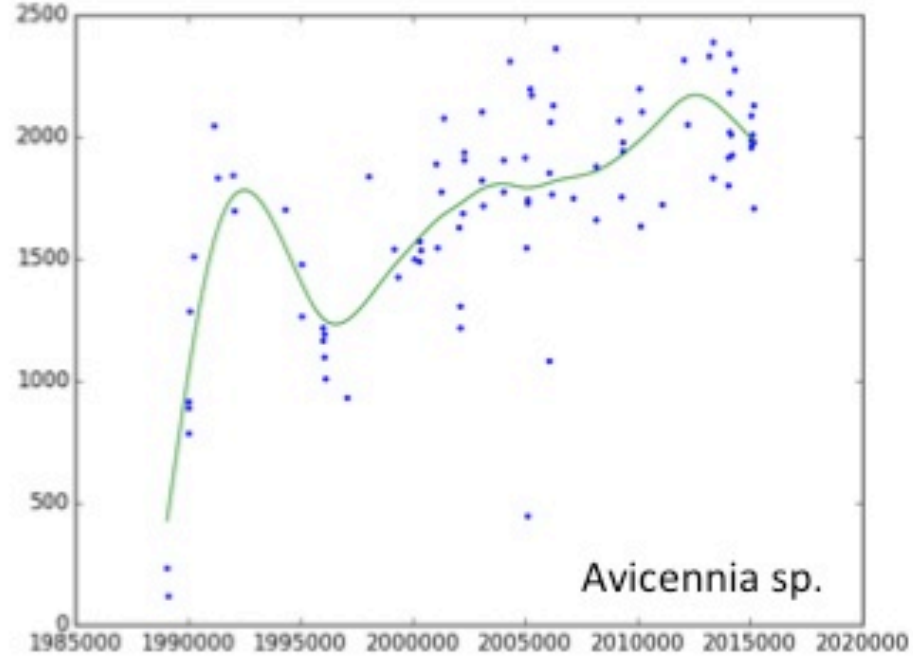
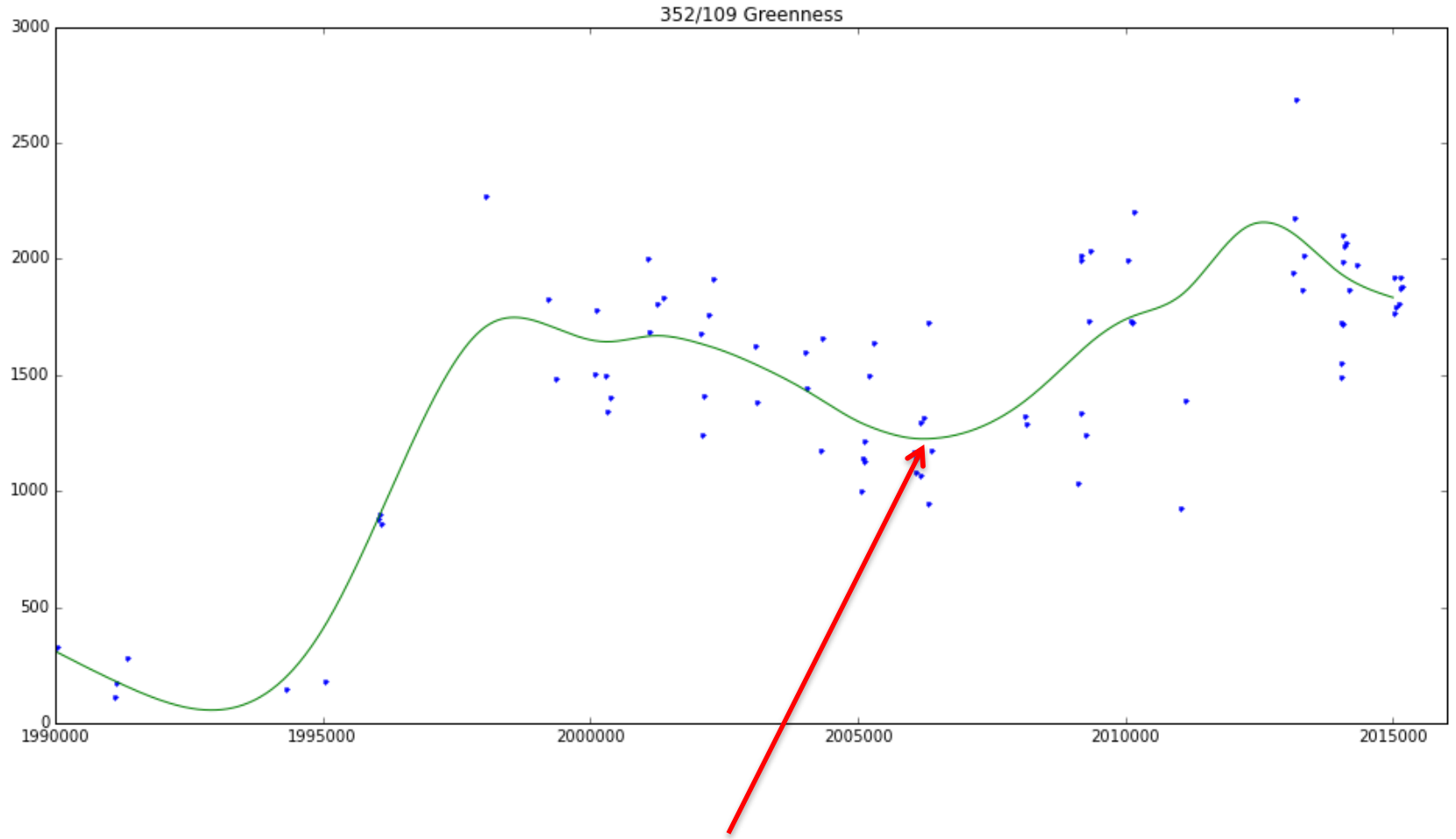

2500
2000
1500
1000
500
0
1985000
1990000
1995000
2000000
2005000
2010000
2015000
2020000
Nypa fruticans


2500
2000
1500
1000
500
0
1985000
1990000
1995000
2000000
2005000
2010000
2015000
2020000
Corniculatum sp.

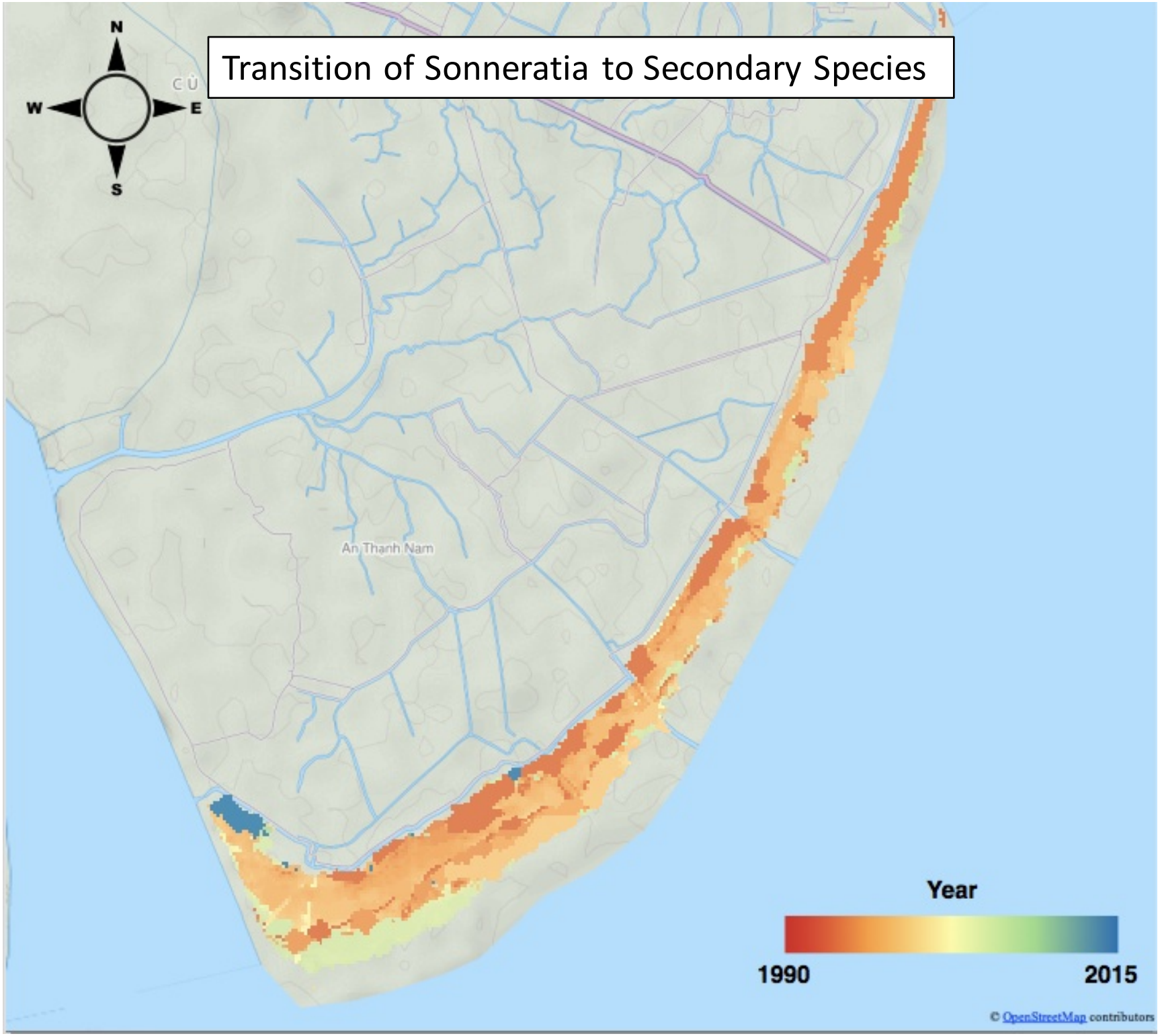

2500
2000
1500
1000
500
0
1985000
1990000
1995000
2000000
2005000
2010000
2015000
2020000
Sonneratia


2500
2000
1500
1000
500
0
1985000
1990000
1995000
2000000
2005000
2010000
2015000
2020000
Avicennia sp.

Spline Smoothing



species transition


Transition of Sonneratia to Secondary Species
N
W
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Year
1990
2015
© OpenStreetMap contributors

Lessons Learned (Mangroves)

- Different mangrove species exhibit different patterns in greenness through time
- Lots of observations affords the opportunity to track species transitions in mangroves

Overall Lessons:

- More observations improve many kinds of uses of optical remote sensing:
  - Change monitoring
  - Forest composition mapping
  - Monitoring pest infestations (Gypsy moths) as they occur
  - Mangrove species transitions

"the more observations you have, the more subtle the changes in landscapes you can find and the more management relevant it becomes"

Software available: https://github.com/beeoda